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A Clinical Comparison of a Binocular Near and Distance Jackson Crossed Cylinder Tests for Astigmatism

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Abstract

A nearpoint card was designed for detecting changes in astigmatism at near. The procedure involves vertical prism for partial dissociation of the nearpoint target and the JCC lens for testing of the astigmatic axis and power. 40 P.U.C.O. students were selected for participation in this study. The study compares the experimental procedure to the commonly used distance monocular JCC procedure. Results show the experimental card to most often provide equal or improved near visual acuity as compared to the distance JCC results.

Introduction

Most commonly, final spectacle correction for astigmatism is determined by a monocular refractive procedure performed at 6M. This same astigmatic correction is most often the one prescribed for near work as well. Studies have shown that nearpoint visual posture may alter the necessary astigmatic correction, making it different from that obtained by a monocular, distance refraction such as Distance JCC.[1-5]

Some factors which can influence these changes in astigmatism from far to near include accommodative astigmatism, cyclophoria, spectacle lens effectivity, changes in corneal curvature and lenticular irregularities which affect the crystalline lens shape during accommodation. We will discuss these factors briefly and introduce a proposed binocular technique which may be used to detect changes in astigmatism at near.

<u>Accommodative astigmatism:</u> Brzezinski defines accommodative astigmatism as "The component of residual astigmatism which occurs as a result of accommodation."[6] This is an astigmatic error which is beyond that measured when accommodation is not active. This error is thought to be accidental and not purposeful as in the case of "astigmatic accommodation" which has been suggested by Dobrowolsky[7] and is also described by Brzezinski.[6] Accommodative astigmatism comes about from an asymmetric contraction of the ciliary muscle and/or zonules and may thus cause a change in lenticular astigmatism over the range of accommodation.

<u>Cyclophoria:</u> As defined by Scobee is " A tendency for the vertical axes of the two eyes to lose parallelism with the median plane of the head."[8] Rabbetts describes three types of cyclophoria.[9] Primary cyclophoria is that manifest when the two eyes are binocularly fusing laterally and vertically, but not along the longitudinal axis. This type of phoria could manifest while superimposing two circular objects - fusing laterally and vertically but yet rotation of the eyes could occur without affecting the binocular percept.

Secondary cyclophoria occurs under monocular conditions. There is no fusional demand and the eyes can move to a cyclophoric position of rest, much the same as with a lateral or vertical phoria. In different positions of gaze, this secondary cyclophoria may vary. This is thought to be due to the secondary actions of the extra-ocular muscles when the eyes deviate to their lateral and vertical phoric postures. The third type of cyclophoria is the sum of primary and secondary cyclophoria and is known as total cyclophoria. Rabbetts goes on to describe the measurement of cyclophoria using a cyclophorometer.[9] When determining the axis of astigmatism under monocular conditions, the astigmatic axis remains relative to the cyclophoric position of the eye. When binocular viewing is allowed, the eyes will rotate from their cyclophoric position to a position facilitating fusion. This may now change the required position of the correcting cylinder axis due to the cyclofusional rotations of each eye.

Spectacle lens effectivity: This astigmatism is produced due to a reduction in the correcting spectacle lens effectivity at near. Since the spectacle correction is placed a certain vertex distance in front of the cornea, the correcting cylinder lens doesn't afford the same effectivity over the range of observation distances as, for instance, a contact lens correction would. Bannon found that much of the clinically measured increase in astigmatism was due to this phenomenon.[5] Several formulas have been derived to calculate the loss in effectivity[10,11] but use of these formulas clinically would be impractical. Estimations of the loss of spectacle effectivity show a need for an approximately 8-10% increase in cylinder power at near.[5,10,11] This becomes clinically significant only in astigmatic corrections greater than approximately 2.00 D.

Corneal curvature changes due to convergence: Investigators have studied the effects of accommodation and convergence on the shape of the cornea. Fairmaid concluded that accommodation without convergence has no effect on corneal curvature but that convergence tended to increase the radius thus flattening the horizontal meridian.[12] The vertical meridian showed a tendency to steepen. Bannon's measurements also found a definite tendency to decrease power in the horizontal meridian during convergence by an average of .25 to .50 D.[5]

Lenticular irregularities: Changing the shape of the crystalline lens is necessary to focus clearly at near through a distance correction. One could easily attribute astigmatic changes during accommodation to unequal forces of the ciliary muscle acting on different meridians of the crystalline lens as in accommodative astigmatism, but according to Duke-Elder, it is believed that if any one part of the ciliary muscle contracts, the entire muscle contracts.[13] Huges reports several cases in which accommodation does act unequally in different meridians of the lens.[14] For example, nearpoint testing of one patient with traumatic rupture of zonule fibers uncovered a detectable difference in need for astigmatic correction from that found when accommodation was inactive. Inhomogeneities (i.e. cataracts) within the crystalline lens may influence lens shape when forces from the ciliary muscle are applied. Tilting of the lens around the vertical or horizontal axis may also be a reason for an increase or decrease in astigmatism.[13,15]

A more comprehensive discussion of all above listed factors lending to a change in nearpoint astigmatism has been presented in papers by Nicholson/Garzia[15], Bannon[5], and Brzezinski[6].

As can be seen from this brief discussion, many factors are present which may affect astigmatism at near. When a situation presents itself which indicates a need for nearpoint astigmatism testing, there may be some confusion as to how to proceed. Obviously, this testing must take into account the posture of the near task including binocular fusion and active accommodation. Also, most would argue that a subjective endpoint would be superior to an objective one.

An experimental card was developed to test for these changes in astigmatism from far to near. The aforementioned factors were all considered in the design. It is a printed card which can be used on the nearpoint bar of most phoropters. It was designed to be used with a vertically dissociating prism and a Jackson Crossed Cylinder lens.

The card itself is imprinted with two identical star shapes which are aligned vertically (see Figure 1)

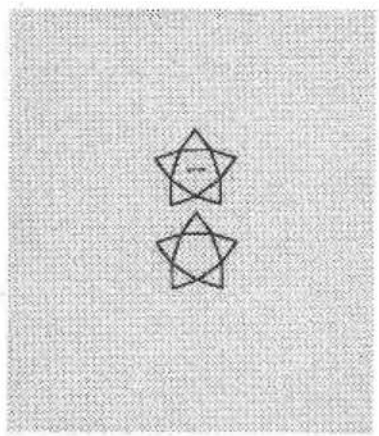


Figure 1

In the center of the top star shape is a line of 20/30 equivalent Snellen letters , the center of the bottom star shape remains empty. Base down prism is used over, for demonstration purposes, the right eye to upwardly dissociate the near target. The amount of prism necessary to vertically dissociate the target to meet the requirement of the card (2.2cm) must be carefully calculated:

2.2 cm vertical dissociation necessary ÷ x meters from front of prism to card = amount of prism utilized base down for testing.

This is done so that the subject is required to use the same binocular posture as is required for habitual fusion at near, regardless of their vertical or horizontal phoric posture.

The bottom of the two stars seen by the right eye should now be placed on the same horizontal meridian as the top of the two stars seen by the left eye (see figure 2). In the absence of any significant horizontal or vertical phoria, these two stars should be easily fused creating an effective fusion lock. The target appearance at this point will consist of three stars aligned vertically (see Figure 3).

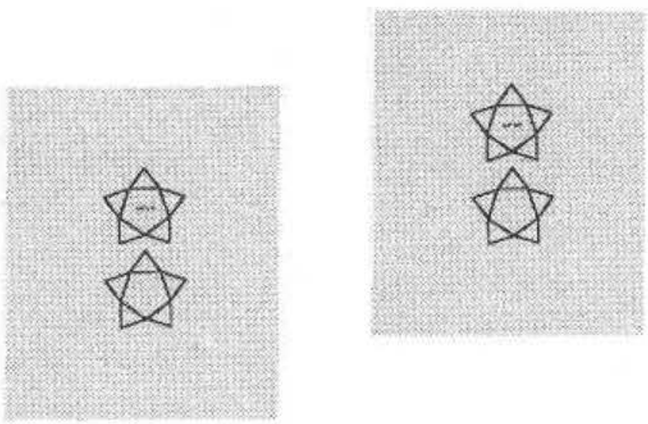


Figure 2

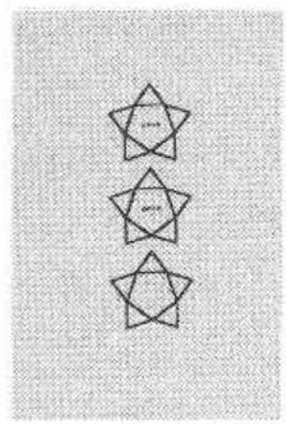


Figure 3

Each eye observes two of the three stars. In the binocular percept, the center star is comprised of two superimposed star shapes. The left eye sees a star surrounding a single line of letters and the right eye sees a star which is "empty". Superimposition of the star shapes allows binocular nearpoint posture while effectively "suspending" central vision of the right eye.

The observer is now instructed to attend to the letters inside the middle star of the three star shapes. Under these conditions, unilateral astigmatism testing of the left eye can be performed in a fused, binocular nearpoint posture.

The star shape was chosen because of it's many oblique lines. Initially, simple shapes including those with predominately horizontal lines were considered but would not allow for a consistent fusion lock. This was probably due to the effects of lateral heterophorias and the lateral sliding effects of fusion along horizontal lines. Since the testing depends largely on second degree fusion (superimposition) the shapes must be identical and provide a solid fusion lock even in the presence of significant lateral, vertical and/or cyclophoria. With a standard phoropter, the Risley prism can be placed in front of one eye while the other eye may be tested for astigmatism with the JCC lens. This procedure could also be performed out of phoropter in the patients true habitual reading position. The subject is instructed to attend to the letters in the center star during the procedure since these letters are only seen by the eye opposite the prism dissociated eye. With attention aimed at these letters, fusion of the targets must come easily and remain stable.

Accommodation is intentionally allowed to remain active during testing. For this reason the test letters must be fairly small to keep accommodative lag to a minimum and to reduce the subjects "just noticable difference" (JND). As Bannon points out, smaller letters provide the best target.[9] A demand of 20/30 was chosen to force accommodation to posture as near to the plane of the card as possible.

All factors which could possibly affect performance and outcome of the testing were to remain active so that we could compare fully functioning visual systems. So as not to bias the experimental results, presbyopic individuals were excluded from participation. Preliminary testing of several presbyopes shows promise when the near lens sphere power is used as a preset lens.

As will be seen in the testing protocol, no comparisons of distance visual acuity between test results were made. Our intention is to compare the results of a popular procedure for prescribing an "all-purpose" astigmatic correction to our experimental procedure, which is designed specifically for determining astigmatic correction at near.

Our belief is that if the experimental card results correlate well with the accepted distance procedure results in a sample population, it is likely to perform well in individual, anomalous cases.

Methods

Forty-one graduate students were recruited from among the population of Pacific University College of Optometry. Our subjects consisted of 25 males and 16 females. All subjects were between the age of 20 and 42. The average age of the students was 25.8. Requirements for participation were as follows: 1) Have no strabismus. 2.) Have had an optometric exam within the last year. 3.) Have best corrected visual acuity of at least 20/30 both at distance (6M) and near (40 cm) 4.)Have an accommodative amplitude sufficient to clear the near test card through their best distance correction and 5.) Have the ability to properly fuse the near binocular test card under the testing conditions described earlier. Of the subjects screened, only one was eliminated from the study due to his large vertical duction capabilities. This subject repeatedly overcame the vertical dissociating prism utilized during the procedure, making proper testing impossible.

The following data was collected on each subject:

Monocular distance acuities were taken through the subjects most recent BVA lens findings from the current files at Pacific University College of Optometry.

The Bichrome test was then performed for each eye according to the procedure described by Carlson.[16] The "first green" response was recorded and was used as the spherical preset lens during the Distance JCC procedure.

The Distance JCC, was administered using the procedure also described by Carlson.[16] Monocular and binocular 6M visual acuities were taken through these results.

A Near Monocular JCC test was then performed, utilizing the designed near card. This near test was performed using the same preset lens and procedure as the distance JCC test, the only change being a 40 cm testing distance. Near monocular visual acuities were then taken through the findings.

The third and last procedure performed was the binocular near JCC test using the experimental card. Again, the same spherical preset lens was used. The right eye was tested first so the Risley prism was placed over the left eye. The amount of prism required for testing was 6.5Δ base down (2.2cm ÷ .34 m from front of prism to card). The JCC lens was placed over the right eye and tested at 40 cm in the same manner as described for distance. The subjects were instructed to attend only to the letters within the center star of the three star shapes to make their assessments during this procedure. The subjects were repeatedly reminded during testing that they were to see three star shapes. If at any time they saw more or less than three, they were to mention this to the examiner. This would alert the examiner to the subject suppressing an eye (subject sees only two star shapes), or losing proper fusion (seeing four star shapes).

Monocular acuities in a binocular posture were determined post-test by using an acuity card design similar to the test card. The single line of letters within the star was replaced with a reduced letter chart. This was printed on the reverse side of the test card so that we could simply rotate the card on the nearpoint bar. With the Risley prism still in place, a monocular visual acuity determination could be made while the subject was still in the binocular nearpoint posture.

Near binocular visual acuities were documented through both the Distance JCC results and the Near Binocular JCC results. A subjective comparison of clarity between results was also requested of each subject. The subjects were then asked two post-test questions:

1. Which test was easiest to respond to?
2. Did you find any test difficult to respond to?

The above procedures were then repeated by the other examiner in the same testing room so as to eliminate any differences between equipment.

Results

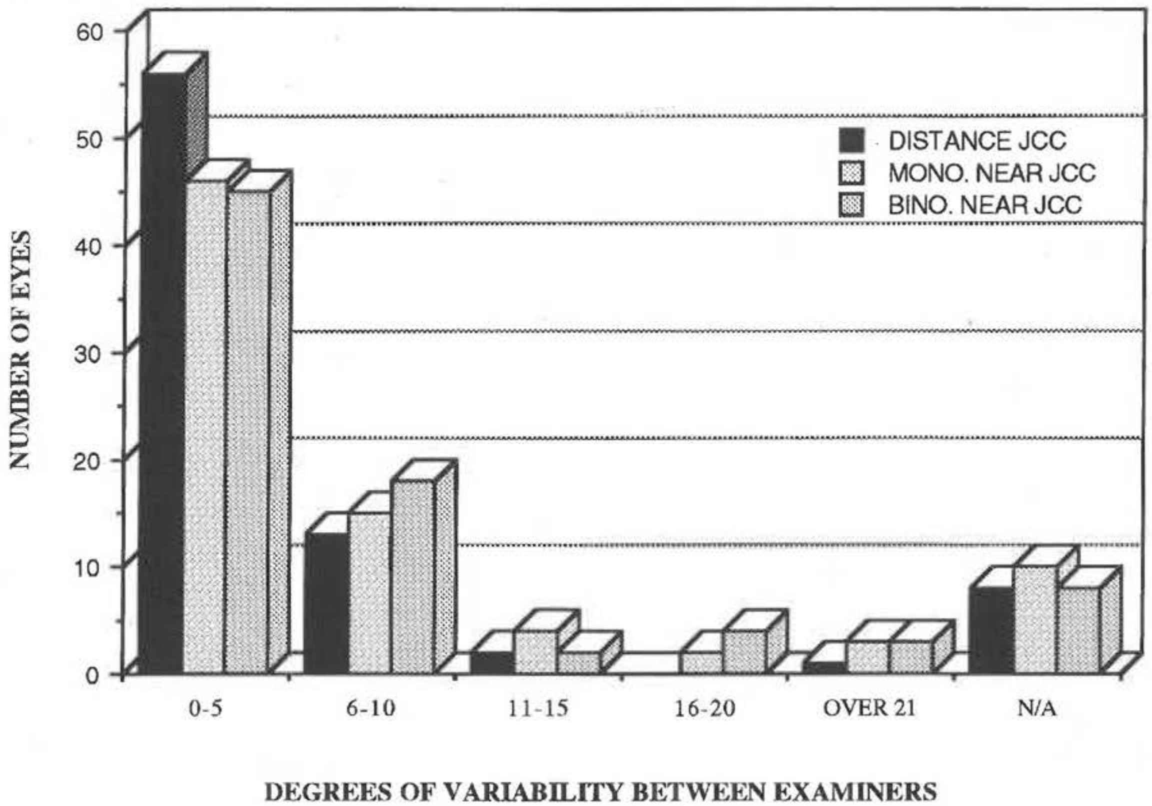
AXIS COMPARISON

Previous studies done at P.U.C.O. point out the problems inherent when attempting a statistical analysis of axis differences between different procedures.[17,18] The statistical evaluation of axis differences is very difficult. For example, comparison of an axis of 170 degrees with an axis of 5 degrees produces a statistical difference of 165 degrees while the clinical difference is only 15 degrees. As in these previous studies, frequency histograms were chosen to show any comparison of axis.

Several eyes showed spherical results in one test while the same eye yielded some astigmatism in another. For analysis, this data was considered to show a difference in the power of the cylinder and was not used in the analysis of astigmatic axis. Thus, any data which shows the subject having a spherical result in one test and an astigmatic result in another was not considered applicable for the comparison of axis. These results were however used in the comparison of astigmatic power.

Histogram 1 was prepared to compare axis findings found by the two examiners (interclinician variability). For example, the axis found by one clinician during the distance JCC test on the right eye was compared with the Distance JCC axis found by the other examiner on the same eye. Differences were plotted for the right and the left eyes for all three tests.

INTERCLINICIAN VARIABILITY

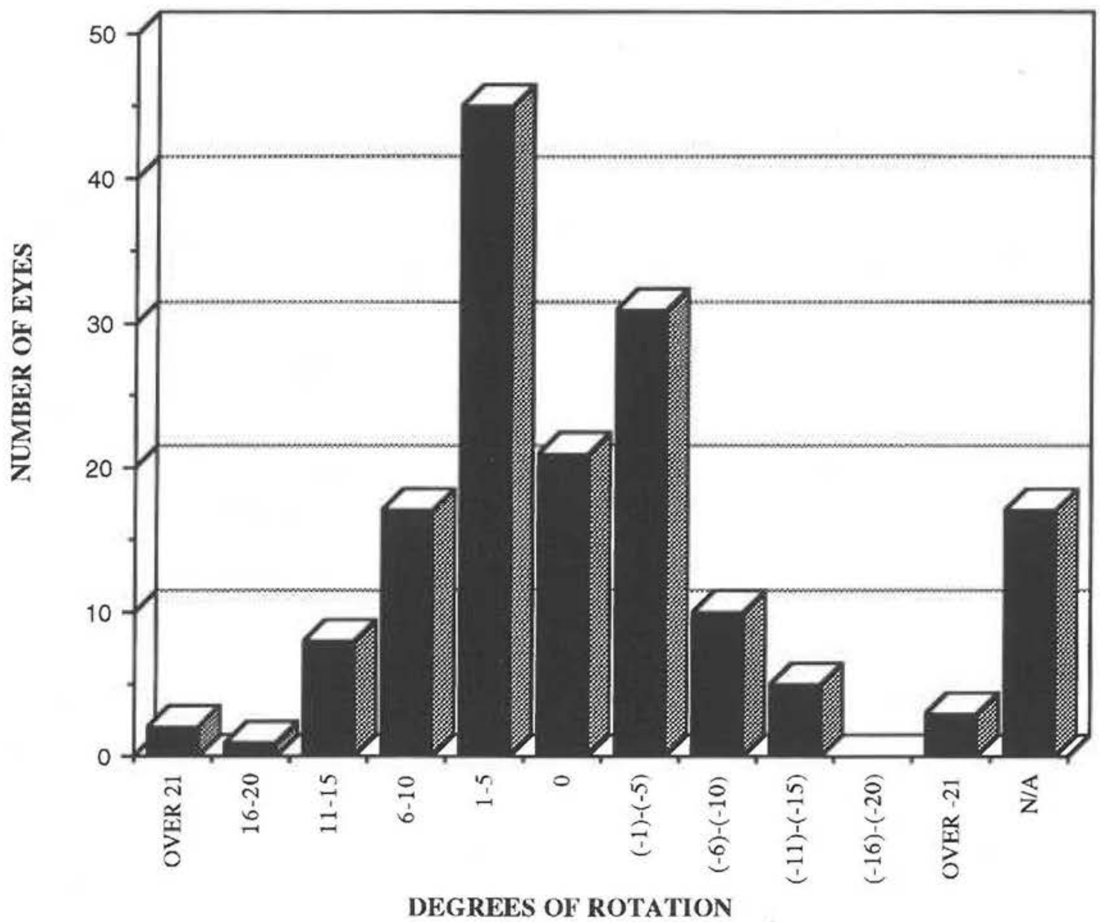


HISTOGRAM 1

The comparison of interclinician variability shows that there were three instances where there was greater than a 10 degree axis difference between clinicians using the distance JCC procedure. Using the monocular near JCC test there were nine instances in which there was greater than a 10 degree axis difference between clinicians. In the binocular near JCC test there were also nine instances where the axis difference between clinicians was greater than 10 degrees.

The next results compared were the axes found for each eye by the three JCC tests. Histogram 2 compares the axis differences between the distance JCC and the near monocular JCC. These changes were determined using the axis found with the distance JCC procedure as the zero point from which axis cyclorotation was calculated.

DISTANCE TO NEAR MONOCULAR AXIS CYCLOROTATION

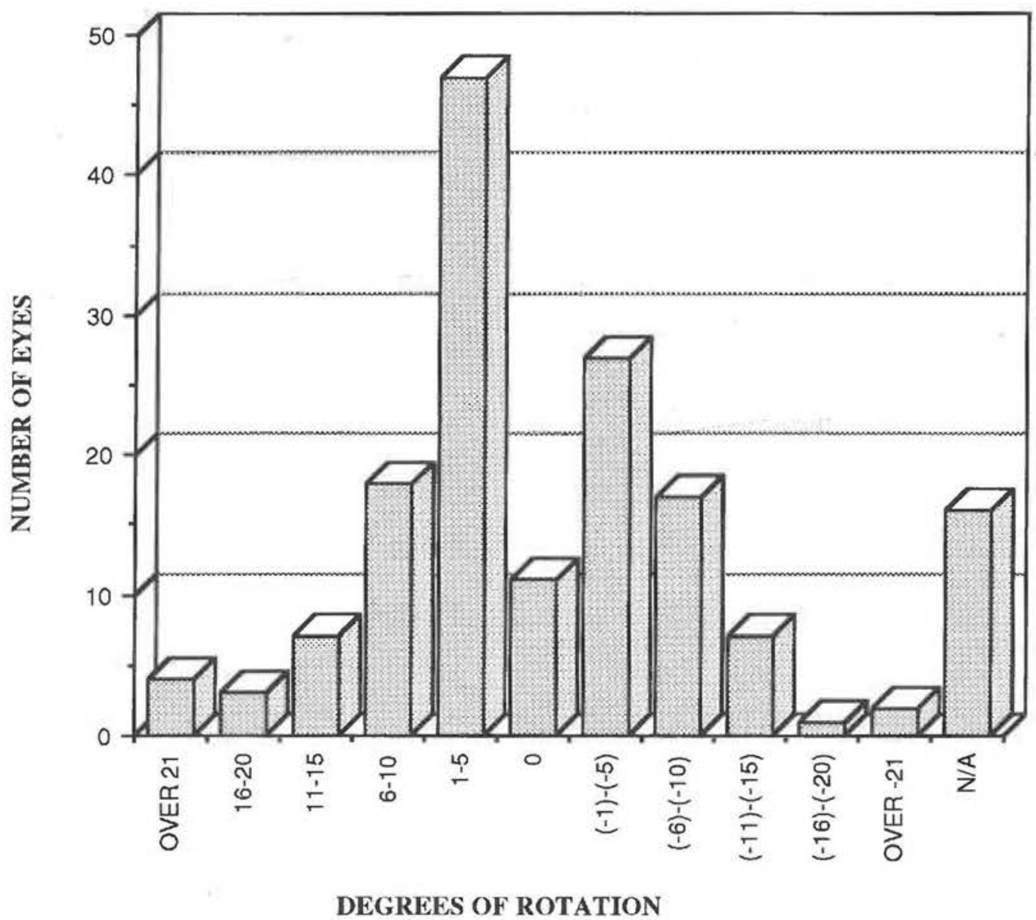


HISTOGRAM 2

Histogram 2 provides the following conclusions about the comparison of cylinder axis of the distance JCC test and the near monocular JCC test. Approximately 61% of the eyes tested had an axis rotation of ± 5 degrees or less. Approximately 17% of the eyes had an axis rotation greater than ± 5 degrees but not greater than 10 degrees, while approximately 11% of the eyes had an axis rotation of greater than ±10 degrees. Approximately 46% of the axes excyclorotated and approximately 31% incyclorotated.

Histogram 3 shows the axis differences between the distance JCC and the near binocular JCC results. Once again, the distance JCC axis findings were used as the zero point from which axis cyclorotation was calculated.

DISTANCE TO NEAR BINOCULAR AXIS CYCLOROTATION

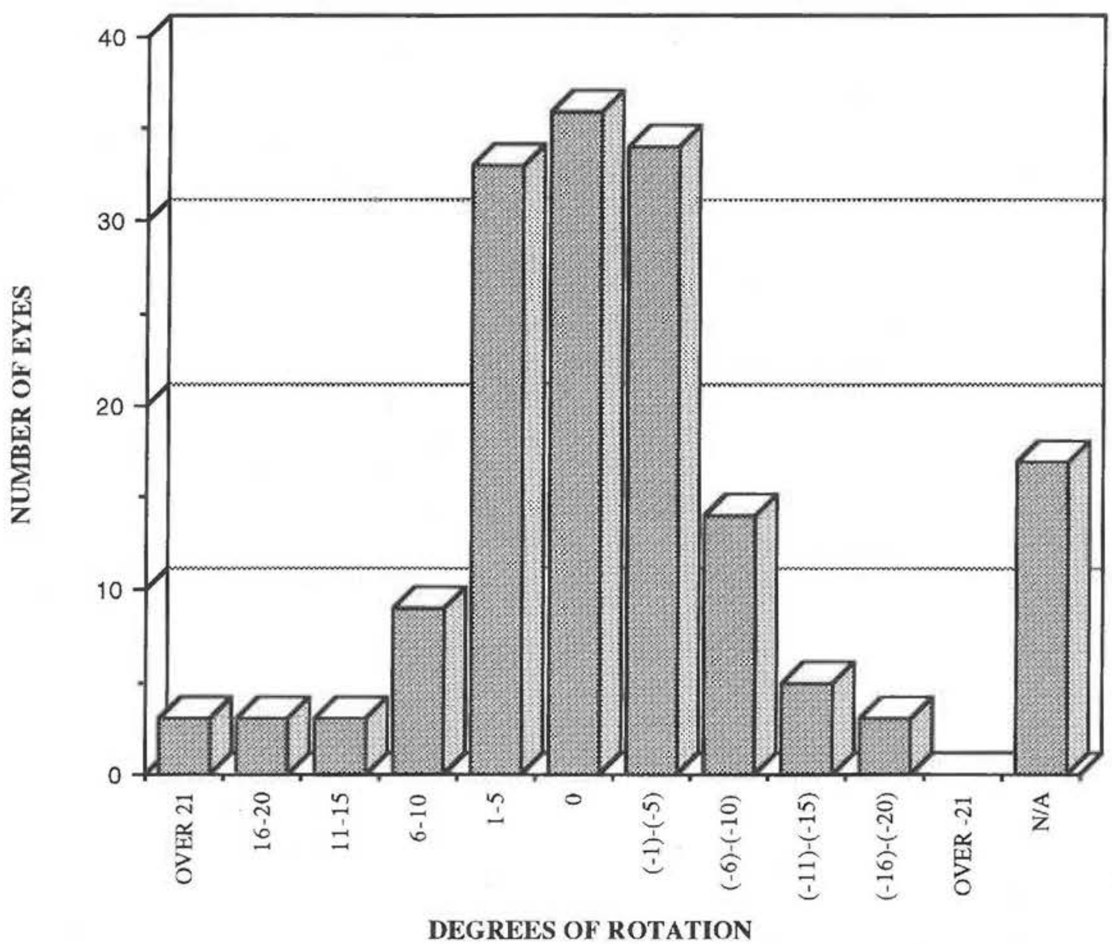


HISTOGRAM 3

Histogram 3 provides the following conclusions about the comparison of cylinder axis of the distance JCC test and the near binocular JCC test. Approximately 50% of the eyes tested had an axis rotation of ± 5 degrees or less. Approximately 22% of the eyes had an axis rotation greater than ± 5 degrees and less than or equal to 10 degrees, while approximately 15% of the eyes had an axis rotation of greater than ±10 degrees. Approximately 49% of the axes excyclorotated and approximately 34% incyclorotated.

Histogram 4 shows axis differences between the monocular JCC and the binocular JCC procedures at near with the monocular near axis being the zero point from which axis cyclorotation was calculated. In all cases excycyclorotation of the axis is represented by a positive number and incyclorotation of the axis is represented by a negative number. The cyclorotation mentioned in these comparisons is not necessarily indicative of a cyclorotary eye movement. For ease of explanation, it is considered a cyclorotation of axis only - regardless of cause.

NEAR MONOCULAR TO NEAR BINOCULAR AXIS CYCLOROTATION



HISTOGRAM 4

Histogram 4 provides the following conclusions about the comparison of cylinder axis of the near monocular JCC test and the near binocular JCC test. Approximately 64% of the eyes tested had an axis rotation of ± 5 degrees or less. Approximately 14% of the eyes had an axis rotation greater than ± 5 degrees and less than or equal to ±10 degrees, while approximately 11% of the eyes had an axis rotation of greater than ±10 degrees. Approximately 32% of the axis excyclorotated and approximately 35% incyclorotated.

Comparing the axis rotation in eyes with 1.50 diopters of astigmatism or more provided the following information when comparing the near binocular JCC axis with the distance JCC axis. Twelve eyes incyclorotated with two of those eyes rotating greater than 5 degrees. Eleven eyes excyclorotated with three of those eyes rotating greater than 5 degrees. No eyes cylcorotated greater than 8 degrees.

Comparing the axis rotation in eyes with less than 1.50 diopters of astigmatism provided the following information when comparing the near binocular JCC axis to the distance JCC axis. Approximately 66% of the eyes tested had an axis rotation of ± 5 degrees or less. Approximately 26% of the eyes had an axis rotation between ±5 and 10 degrees, while approximately 8% of the eyes had an axis rotation of greater than ±10 degrees. Approximately 56% of the eyes excyclorotated and approximately 44% incyclorotated.

Relating axis changes in pairs of eyes: In 28.75%, both axes excyclorotated. In 15.0% of eyes, both axes incyclorotated. In 2.5% of the pairs there was no change in axis rotation. There were 27.5% of the pairs of eyes which showed incyclorotation or excyclorotation of the axis in one eye while showing no change of axis in the other. The remaining 26.25% were not considered applicable since one eye showed a spherical result with either the distance or near test and an astigmatic result with the other.

CYLINDER POWER COMPARISON

Interclinician variability of cylinder power was also analyzed. A correlation of the cylinder power for each eye was calculated. The correlations are as follows:

POWER CORRELATIONS

DISTANCE JCC	(OD)	0.956
DISTANCE JCC	(OS)	0.916
MONOCULAR NEAR JCC	(OD)	0.941
MONOCULAR NEAR JCC	(OS)	0.934
BINOCULAR NEAR JCC	(OD)	0.945
BINOCULAR NEAR JCC	(OS)	0.961

All correlations were above 0.90 and thus show a high correlation of the cylinder powers found between the clinicians. The high correlation between examiners allows for the combining of clinician cylinder powers to find a mean cylinder power for each test. A repeated measures ANOVA was then calculated to determine whether there was a significant difference in the cylinder powers found by each test. Results were as follows.

MEANS

DISTANCE JCC CYLINDER POWER	-.812
MONOCULAR NEAR JCC POWER	-.936
BINOCULAR NEAR JCC POWER	-.961

	Mean diff.	Scheffe F test
DISTANCE JCC VS. MONOCULAR NEAR JCC	.124	11.856 $p<0.05$
DISTANCE JCC VS. BINOCULAR NEAR JCC	.149	17.123 $p<0.05$
MONOCULAR NEAR JCC VS. BINOCULAR JCC	.025	0.483 $p>0.05$

These results indicate: 1) The Distance JCC and the Near Monocular JCC are measuring a statistically different cylindrical power. 2) The Distance JCC and the Near Binocular JCC are measuring a statistically different cylindrical power. 3) The Near Monocular JCC and the Near Binocular JCC are statistically measuring the same cylindrical power.

Of the 80 comparisons between Distance JCC cylinder power and Near Binocular JCC cylinder power (40 subjects, both eyes being tested) there were 23 cases in which cylinder power changed in at least one of the subjects eyes by 0.50 diopters or more. In 22 of these cases the cylinder power increased from far to near. In 13 of those cases the subjects preferred the visual acuity obtained with the Near Binocular JCC results to the Distance JCC test results, compared to only 5 cases in which the individual preferred the acuities through the Distance JCC results. The other 4 cases had no subjective preference between the two choices. In the one case in which cylinder power decreased at near the patient preferred the Near Binocular JCC results.

Of the 23 cases showing changes there were 17 in which astigmatism increased in "with the rule" power. Three cases increased in "against the rule" astigmatism and 2 increased in oblique astigmatism. The one case in which cylinder power decreased was a decrease in against the rule astigmatism.

Table 1 shows the preferences of the patients when asked the following questions:

1.) Which of the tests was the easiest to respond to?

2.) Which test was the most difficult to respond to?

3.) When comparing the Near Binocular JCC results with the Distance JCC results (at 40 cm), which lenses give more comfortable vision?

This table also shows which findings provided the patient with the best binocular visual acuities.

Table 1

	Question #1 (easiest)	Question #2 (Most difficult)	Question #3 (comfort)	Best VA (clarity)
Near Mono JCC	7	0	x	x
Near Bino JCC	1	18	26	22
Dist. Mono JCC	23	0	23	10
No difference	7	11	31	48

x: no comparison made

The comparison of visual acuities for each set of lenses presented only four instances in which there was at least one line difference between the two tests. In all four cases visual acuities were better with the near binocular cylindrical results.

Discussion

The results show that there is no statistically, or clinically significant difference between the mean cylindrical powers when comparing the Near Monocular JCC to the

Near Binocular JCC tests. The difference between these means is only 0.025 diopters. A statistically significant difference was found when comparing the mean cylindrical powers determined by the near tests to those determined by the distance test. The difference in mean cylindrical powers when comparing the Distance JCC results and the Near Monocular JCC results is 0.124 diopters, and the difference between the means of the Distance JCC and the Near Binocular JCC mean is 0.149 diopters. Even though this statistical difference was found, it is only approximately one-eighth of a diopter. Thus, it is concluded that there is no clinically significant difference in cylindrical power when comparing the distance JCC results to either of the two near JCC test results. When comparing these means, it is interesting to note that the increase in cylinder power is close to that predicted due to spectacle lens effectivity.

In the comparison of astigmatic axes the results showed that when comparing either of the near JCC results to the Distance JCC results 15% more of the axes excyclorotated than incyclorotated when changing target distance from six meters to 40 centimeters. The amount of axis cyclorotation was primarily within ± 10 degrees. In the three different axis rotation comparisons, an average of only 12% of the axes cyclorotated greater than ±10 degrees. These results suggest that, in this sample population, amount and direction of axis cyclorotation from distance to near is small and reasonably unpredictable.

The accuracy of any crossed cylinder test is dependent on the patients attention and their sensitivity to blur. This sensitivity allows them to discriminate between two, often very similar choices. Due to this subjectivity, it is very difficult to make a statement about which astigmatism test provides the patients exact astigmatic correction. The best indicator we can look for is a definitive improvement in visual acuity.

The results obtained show that the near binocular astigmatism test, which has been proposed, yields astigmatic results similar to those obtained by the Distance JCC procedure. Interestingly, 88% of the subjects tested had equal to or better near acuities through the Near Binocular JCC results than through the Far Monocular JCC results. In 22 cases the experimental near test results provided better visual acuity at near than the standard Distance JCC test results provided at near. This is compared to only 10 cases in which the distance results provided better visual acuities than the near test. In most of these instances, however, the acuity difference was very minute, a few letters in most cases, so it could be argued whether this difference was actually a measurement of increased acuity or more of a measurement of patient consistency or sensitivity during testing.

The proposed near binocular JCC test utilizing the experimental card provides an astigmatic correction which most often matches or exceeds 40 cm best visual acuity as determined by monocular Distance JCC. Although our research provided no instances in which significant changes in astigmatism occurred when changing viewing distances from far to near, there are documented cases of this occurring.[1-5] In such cases, the proposed near astigmatism technique may provide a near prescription for the patient which will allow them to more comfortably perform near tasks. Although this procedure is slightly more involved than a standard distance JCC test, it shows promise for being very useful in anomalous situations.

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